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Creep Resistance of Disk Alloy CH98 With Tungsten and Niobium Additions

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INTRODUCTION

Gas turbine engines for future subsonic transports will likely have higher pressure ratios which will require nickel-base superalloy disks with temperature capability up to 1400F, an increase of about 200F over current engines. Several advanced disk alloys are being developed to fill this need. One of these, CH98, is a promising candidate for gas turbine engines and is being studied in NASA's AST Program. Additions of the refractory elements tungsten and niobium have been shown to improve tensile and creep properties while maintaining good high temperature fatigue crack growth resistance (Ref. 1). Further improvements in creep and crack growth resistance can be achieved with a coarse grain microstructure (Ref. 2). The purpose of the present study is aimed at providing a detailed assessment of 0.2% creep rates for coarse grain CH98 with tungsten and niobium additions over a range of temperatures and stresses of interest to disk applications.

MATERIAL & TEST PROCEDURE

CH98 is a nickel-base superalloy strengthened by gamma prime precipitates. The composition of CH98 with tungsten and niobium additions is shown in Table 1. The levels of these two alloying additions are the same as those used in a previous study (Ref. 1) resulting in a gamma prime content of about 55 volume percent. All material was produced from argon atomized powder which was pre-compacted at 2000F followed by extrusion at 2000F with an 8:1 reduction ratio. Specimen blanks were cut from the extrusion (longitudinal orientation) and HIPed at 2225F/30KSI/3HR to achieve an ASTM 6-8 grain size without introducing porosity. These blanks were then solution heat treated at 2175F/1HR followed by an air cool to achieve an initial cooling rate of about 250F/MIN. After solutioning, the blanks were stabilized at 1550F/2HR and then aged at 1400F/8HR. The stabilization treatment is employed to reduce residual stress levels and thereby improve machinability. In addition, stabilization precipitates $M_{23}C_6$ carbides and tends to increase the size of the gamma prime precipitates. A photomicrograph of the structure is presented in Figure 1. The actual grain size of the heat treated blanks was about ASTM 6.

Tensile and creep specimens were machined from the heat treated blanks using a low stress grinding operation and were of identical design with a cylindrical gage section measuring 0.160" in diameter by 0.750" long. Tensile tests were run at 1200, 1300, and 1400F at a strain rate of 0.5%/minute through yield. Creep tests were run at various temperatures (1200 to 1400F) and stresses (65 to 125KSI) of interest to disk applications. In general, duplicate tests were run to 0.2% creep strain for each condition following the procedure outlined in ASTM E139 specification.

RESULTS & DISCUSSION

The tensile data for all three temperatures is presented in Table 2. Yield and ultimate strength drop with increasing temperature while elongation levels appear to increase with increasing temperature. The tensile strengths reported here are typical for this class of material when a high cooling rate, following solution heat treatment, is employed (Ref. 2).

Typical creep curves for 1300F/95KSI are presented in Figure 2. These curves show the extremes in behavior. While the time to 0.2% agree within a factor of two, the initial response is quite different. One run exhibits a transient acceleration, possibly representing a primary creep regime, but the other run exhibits an incubation period where negative creep strain is observed. In general, the latter behavior was more often observed at lower stresses and may result from residual stresses produced during machining of specimens. Other issues, such as specimen alignment, extensometry, and thermal stability, could also contribute to startup transients which may or may not reflect true material behavior.

Creep data for all the conditions tested in this study are listed in the Table 3. The times to 0.1% and 0.2% creep strain are reported, or for long term tests which did not reach 0.1%, the final creep strain and time is reported in the comment column. To analyze this data, the 0.2% creep time was first plotted against stress, Figure 2. One can readily detect a semi-logarithmic relationship between stress and creep time at each temperature. The regression coefficients and the R^2 values for each line in Figure 3 are reported in Table 4. The intercepts show a significant increase with temperature while the slopes seem to become more negative with increasing temperature.

As creep data is often represented using the Larson-Miller Parameter (LMP), the present data set was reanalyzed using this approach. For this study LMP was calculated using a C=20 and the 0.2% creep time in hours. The results of this analysis are presented in Figure 4. The data fit the relationship with an R^2 value of 0.94 when log stress is plotted against LMP. The regression coefficients for the line in Figure 4 have an intercept of 4.258 and a slope of –5.758. As evident by the high R^2 valued the data are adequately represented by this approach. Interestingly, the data point showing the greatest deviation, 1400F/95KSI, also has the lowest creep time and is the least important from an engineering standpoint as the 0.2% creep time was less than 10 hours.

SUMMARY & CONCLUSIONS

The 0.2% creep times, an important disk design criteria, were measured for a wide range of conditions of interest to disk application using an advanced nickel-base superalloy, CH98 with tungsten and niobium additions. The results showed that the alloy has usable creep strength of 125KSI at 1200F, 95KSI at 1300F, and 70KSI at 1400F, when hot life times of several hundred hours are required.

REFERENCES

1. Gayda, J., The Effect of Tungsten and Niobium Additions on Disk Alloy CH98, AST 016, NASA Report, August 1997.

2. Mourer, D.P., High T3 Disk Alloy Development, LET Contract Report NAS3-26617 Task 8, NASA Report, December 1995.

Table 1. Composition in weight percent.

Ni	Co	Cr	Al	Ti	Mo	Ta	W	Nb	C	B	Zr
Bal	18.3	11.3	3.9	3.8	2.9	2.2	2.3	1.0	.05	.03	.04

Table 2. Tensile data.

Temperature	0.2% Yield	Ultimate	Elongation
1200F	146KSI	209KSI	16%
1300F	141KSI	189KSI	23%
1400F	136KSI	175KSI	23%

Table 4. Coefficients for regression lines shown in Figure 2.

Temperature	Intercept	Slope	R^2
1200F	8.619	-.0481	0.979
1300F	7.968	-.0557	0.931
1400F	6.987	-.0642	0.981

Table 3. Creep data in hours.

Temp(F)	Stress(KSI)	0.1%	0.2%	Comment
1200	125	98	364	
1200	125	220	480	
1200	115	208	1313	
1200	115	220	1045	
1200	105	1717	3924	
1200	105	-	-	936 to 0.03%
1200	95	-	-	3305 to 0.02%
1300	105	60	142	
1300	105	82	148	
1300	95	97	286	
1300	95	455	571	
1300	85	1376	2049	
1300	85	-	-	1153 to 0.07%
1400	95	2	7	
1400	85	25	45	
1400	85	16	33	
1400	75	100	158	
1400	75	58	138	
1400	65	378	616	

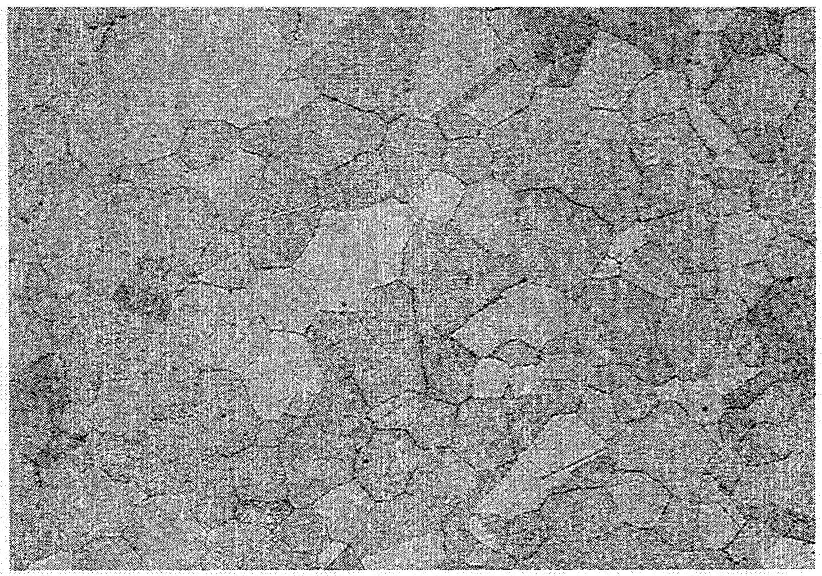

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Figure 1. Microstructure of alloy.

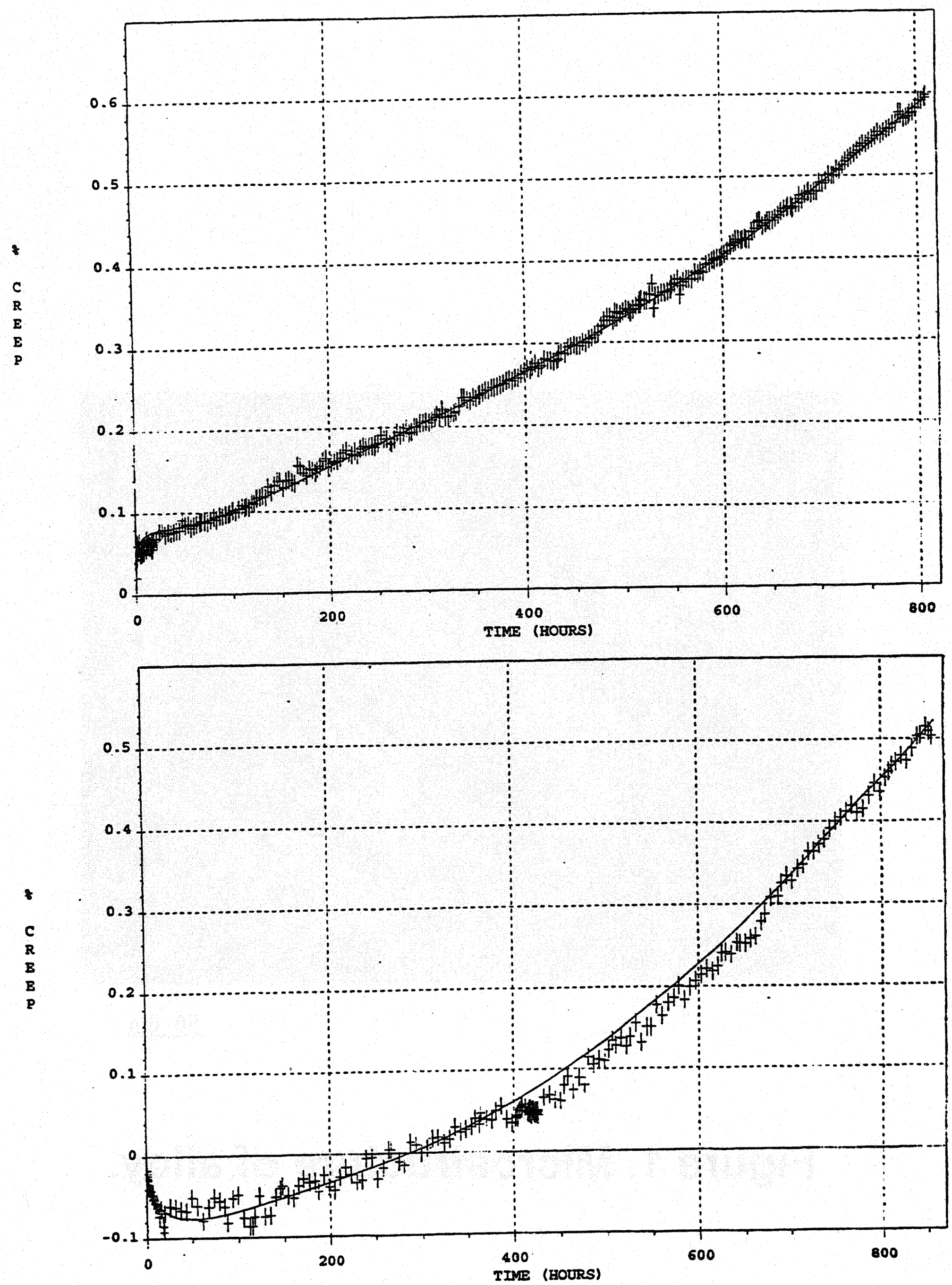

Figure 2. Typical creep curves showing variation in startup transients at 1300F/95KSI.

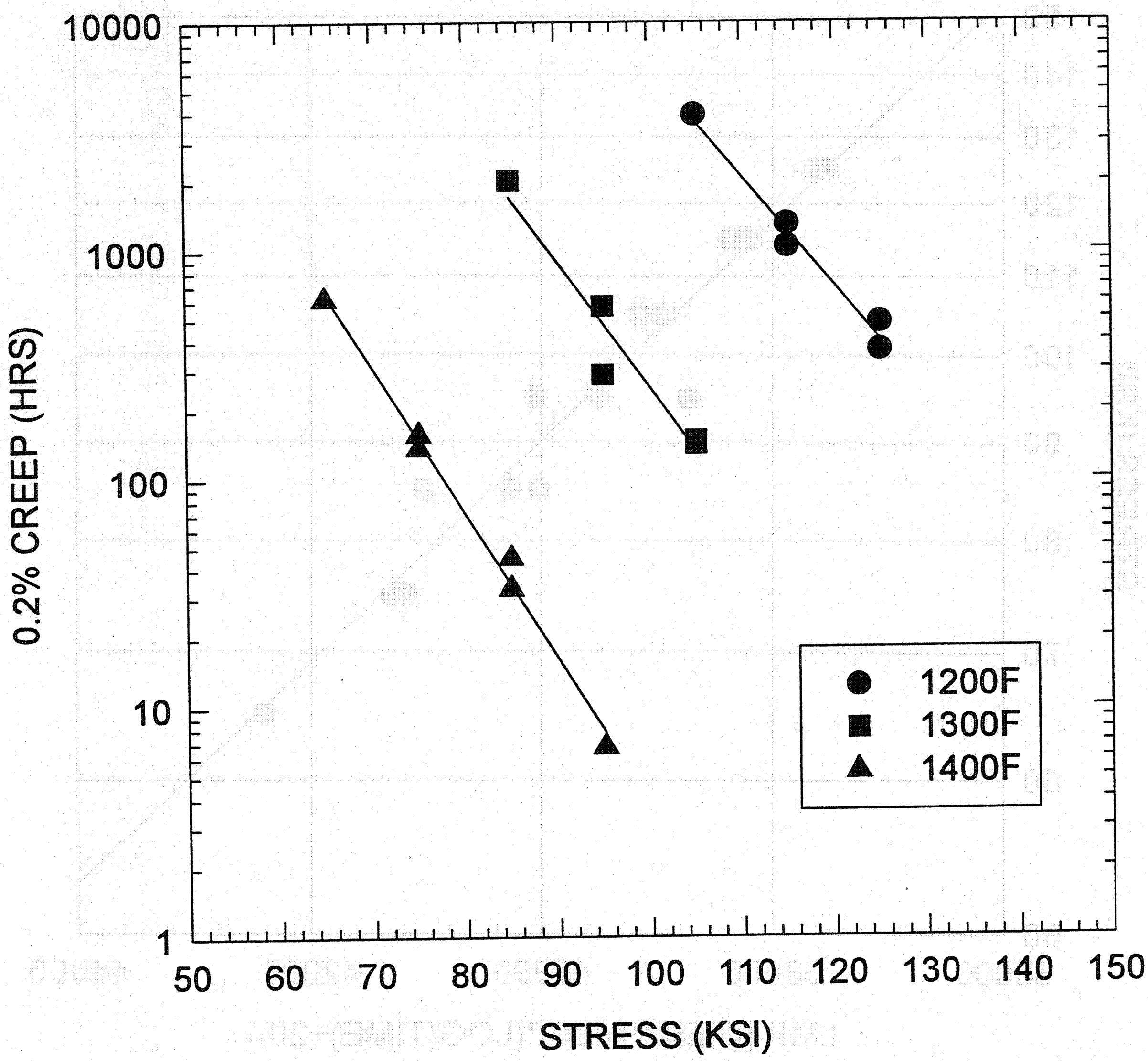

Figure 3. Raw creep data.

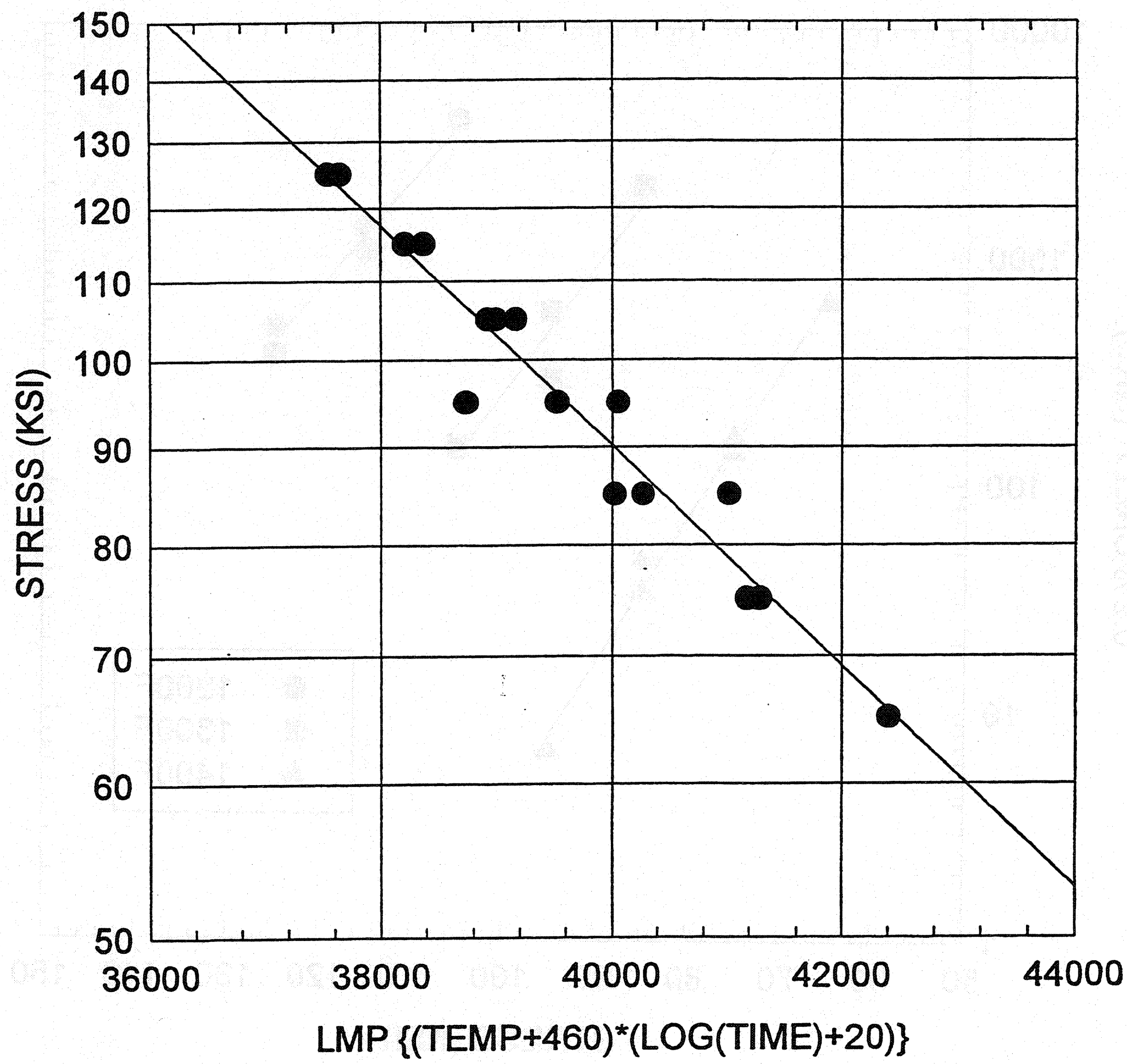

Figure 4. LMP plot for 0.2% creep strain.

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13. ABSTRACT ***(Maximum 200 words)***

Gas turbine engines for future subsonic transports will likely have higher pressure ratios which will require nickel-base superalloy disks with temperature capability up to 1400 °F, an increase of about 200 °F over current engines. Several advanced disk alloys are being developed to fill this need. One of these, CH98, is a promising candidate for gas turbine engines and is being studied in NASA's AST Program. Additions of the refractory elements tungsten and niobium have been shown to improve tensile and creep properties while maintaining good high temperature fatigue crack growth resistance. Further improvements in creep and crack growth resistance can be achieved with a coarse grain microstructure. The purpose of the present study is aimed at providing a detailed assessment of 0.2 percent creep rates for coarse grain CH98 with tungsten and niobium additions over a range of temperatures and stresses of interest to disk applications.

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